Performance Assessment of Concrete with Copper Slag and Eggshell Powder as Partial Replacements for Fine Aggregate and Cement Using Ansys

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Abstract—Concrete today is expected to deliver higher strength and durability while remaining economical and energy efficient. At the same time, it is important to retain the inherent benefits that make concrete a preferred construction material. Growing environmental concerns and the increasing demand for concrete have encouraged the use of alternative materials to enhance its performance and sustainability.
This study focuses on experimentally evaluating concrete in which copper slag (CS) is used as a partial replacement for fine aggregates, and egg shell powder (ESP) is used as a partial replacement for cement. Different mix proportions will be prepared by replacing fine aggregates with copper slag at levels of 0%, 5%, 10%, 15%, 20%, 25%, and 30%, and replacing cement with egg shell powder at the same percentage intervals by weight.
A series of tests will be carried out to assess the mechanical and durability properties of the modified concrete, including compressive strength, split tensile strength, and flexural strength. The results obtained from these mixes will be compared with those of conventional concrete to evaluate how the inclusion of copper slag and egg shell powder influences the overall performance and characteristics of concrete.

Index Terms—Performance of concrete, Use of alternative material, Partial replacement, Strength Properties.

I. INTRODUCTION

The use of industrial by-products and secondary materials has significantly contributed to the advancement of sustainable practices in cement and concrete production. Rapid industrialization has led to the generation of large quantities of waste materials, and their disposal poses serious environmental and health concerns. As a result, recycling these wastes in the construction industry offers a practical and eco-friendly solution. Materials such as construction debris, blast furnace slag, steel slag, coal fly ash, and bottom ash have already been widely adopted as alternative aggregates in applications like embankments, pavements, foundations, and building construction, as well as raw materials in the production of ordinary Portland cement.).

Among these, copper slag has gained attention due to its suitable mechanical and chemical properties, making it a viable material for use in concrete either as a partial replacement for fine aggregates or even cement. Studies, including those by Teik Thye Luin (2006), highlight its potential in cement manufacturing. Copper slag demonstrates favorable characteristics such as high soundness, strong resistance to abrasion, and good overall stability, as reported by Gorai et al. (2003). Additionally, its low calcium oxide (CaO) content contributes to its pozzolanic behavior, enhancing its performance in concrete mixtures.

In this context, egg shell powder (ESP) emerges as a promising waste material for partial cement replacement. Egg shells, which are produced in large quantities globally, are often discarded, leading to disposal issues. They are primarily composed of calcium carbonate and contain significant amounts of calcium and bicarbonates, making them suitable for use in cementitious applications. In this study, egg shell powder is used as a partial replacement for cement at varying proportions of 0%, 5%, 10%, 15%, and 20% by weight, contributing to both waste reduction and sustainable construction practices.

II. OBJECTIVE

The scope of the work involves assessing the mechanical properties of concrete, including compressive strength, split tensile strength, and flexural strength. These properties will be analyzed for different mix proportions in which fine aggregate is partially replaced with copper slag and cement is partially replaced with egg shell powder. The results will help in understanding the effects of these replacements on the overall behavior and strength characteristics of concrete aggregate and cement by (0%+0%), (5%+5%), (10%+10%), (15%+15%), and (20% +20%) using M40 grade of concrete.

III. MATERIALS USED

CEMENT

Ordinary Portland Cement (OPC) is primarily composed of compounds such as calcium silicates, calcium aluminates, and calcium aluminoferrites. It is manufactured by carefully blending limestone, clay, and small quantities of other minerals in specific proportions. This mixture is finely ground and then heated in a kiln at a high temperature of about 1500°C to form clinker.

Table 1 Properties of Cement

Properties	Results
Specific Gravity	3.16
Fineness	2.6
Initial Setting time	40 min
Final Setting time	10 hours

AGGREGATE:

Normally Sand is used as fine aggregate for preparing concrete. An individual particle in this range is termed as Sand grain. These sand grains are between coarse aggregate (2mm to 64mm) and silt (0.004mm to 0.0625mm). Aggregate most of which passes through 4.75mm sieve is used. The Coarse aggregate for the work should be rivergravel or crushed stone. Angular Shape aggregate of size is 20mm and below. The aggregate which passes through 75mm sieve and retain on 4.75mmare known as coarse aggregate.

Table 2 Properties of Fine Aggregate

Properties	Results
Specific Gravity	2.83
Water Absorption	0.8%
Fineness	36.9%

Table 3 Properties of Coarse Aggregate

Properties	Results
Specific Gravity	2.75
Water Absorption	1%
Fineness	21.5%

EGG SHELL POWDER

The egg Shell is the hard outer shell of the egg. It mainly consists of calcium carbonate $CaCO_3$, normal calcium. The rest is made up of proteins and other minerals. Calcium is an essential mineral and is found in many foods, including dairy products. Egg shell chopper is used to process egg shell into egg shell powder. Egg shell consist of $CaCO_3$ and it is a poultry waste to replace cement can have benefits like minimizing use of cement., conserves a natural lime and utilising waste materials.

Fig 1 Egg shell powder

Table 4 Properties of Egg Shell Powder

Properties	Results
Specific Gravity	1.73
Fineness	3.66%

COPPER SLAG

Copper Slag is a by-product material produced from the process of manufacturing copper. The slagis a black glassy and granular in nature and has a similar particle size range like sand. As the coppersettles down in the smelter, it has a higher density,impurities stay in the top layer and then are transported to a water basin with a lot oftemperature for solidification.

Fig 2 Copper Slag

Table 5 Properties of Copper Slag

Properties	Results
Specific Gravity	3.1
Water Absorbed	0.4%

IV. EXPERIMENTAL METHODS

1. Concrete Mix Design

The mix design is done by the various proportions of materials for M30 grade concrete which is used in the present study. Then the mix design is designed as per IS 10262-2009 standards.

Table 6 Mix Design Proportions

Cement kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Water kg/m^3
348	868	1032	195
1	2.5	3	0.40

2. Casting of Specimen

Cubes of Size 150mm x150mm x150mm, Cylinderof size 200mm x 300mm, Beam of size 700mm x150mm x 150mm were casted. The materials which are mixed by coarse aggregate,manufactured sand, cement, egg shell powder, Copper slag and water. After the moulds were casted and compacted. Demoulding was done after24 hours of casting and specimens were allowed tocured in a water tank.

V. CONCRETE TESTS AND RESULTS

FRESH CONCRETE TESTS

SLUMP CONE TEST in M40 Grade Concrete

Table 7 Slump Cone Test

S.NO	% Replacement	Slump (mm)
1	0% CS + 0% ESP	0
2	5% CS + 5% ESP	25
3	10% CS + 10% ESP	27
4	15% CS + 15% ESP	30
5	20% CS + 20% ESP	35
6	25% CS + 25% ESP	50
7	30% CS + 30% ESP	75

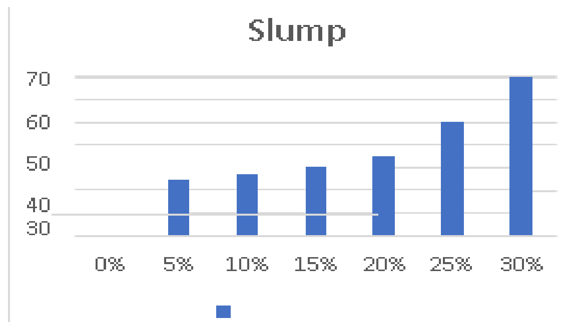

Fig 3 Slump Cone Test

COMPACTION FACTOR TEST in M40 Grade

Table 8 Compaction factor Test

S.NO	% Replacement	Compactionfactor
1	0% CS + 0% ESP	0.98
2	5% CS + 5% ESP	0.94
3	10% CS + 10% ESP	0.90
4	15% CS + 15% ESP	0.88
5	20% CS + 20% ESP	0.86
6	25% CS + 25% ESP	0.82
7	30% CS + 30% ESP	0.78

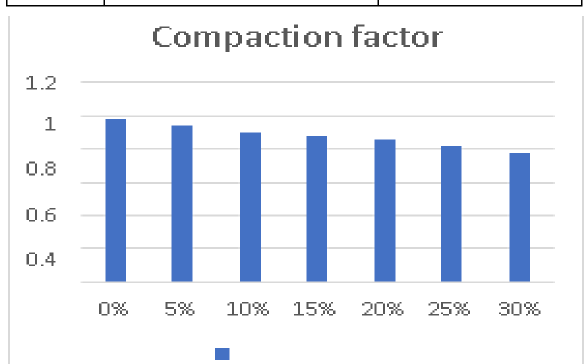

Fig 4 Compaction factor Test

HARDENED CONCRETE TEST

The variation among individual specimens did not exceed ±15% of the average value. Specimens cured in water were tested immediately after being removed from the curing tank. Before testing, each specimen was wiped clean, and its dimensions and weight were recorded.

During placement in the compression testing machine, care was taken to ensure that the load was applied on the faces opposite to those cast, rather than on the top and bottom surfaces.

The maximum load applied to each specimen was recorded, and any unusual characteristics in the mode of failure were carefully observed and noted.

COMPRESSIVE STRENGTH OF CONCRETE

Table 9 Compressive strength test

S.NO	%Replacement	Compressive Strength		
		7 days	14 days	28 days
1	CS + 0%ESP	36.60	37.45	38.80
2	CS + 5%ESP	36.85	38.10	39.40
3	10% CS +10% ESP	38.24	39.75	41.10
4	15% CS +15% ESP	39.60	40.20	43.75
5	20% CS +20% ESP	37.45	39.15	42.10
6	25% CS +25% ESP	35.22	37.40	39.05
7	30% CS +30% ESP	32.80	33.45	35.03

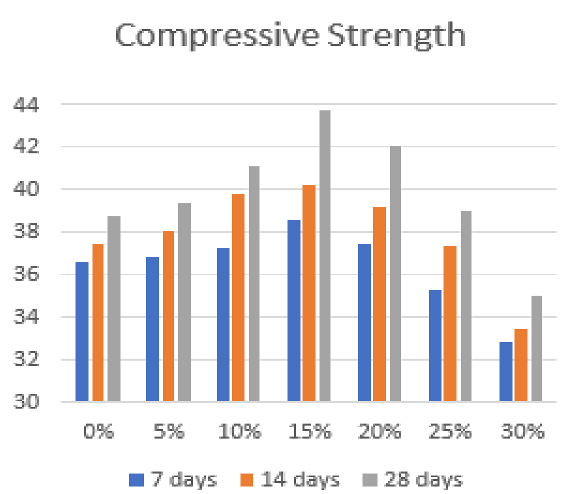

Fig 6 Split Tensile Strength Test

SPLIT TENSILE STRENGTH TEST

Table 10 Split tensile strength Test

S.NO	% Replacement	Tensile Strength		
		(7 days)	(14 days)	(28 days
1	0% CS + 0% ESP	3.78	3.86	3.96
2	5% CS + 5% ESP	3.83	3.95	4.02
3	10% CS + 10% ESP	3.98	4.05	4.24
4	15% CS + 15% ESP	4.02	4.16	4.37
5	20% CS + 20% ESP	3.92	4.06	4.23
6	25% CS + 25% ESP	3.84	3.92	3.98
7	30% CS + 30% ESP	3.72	3.85	3.84

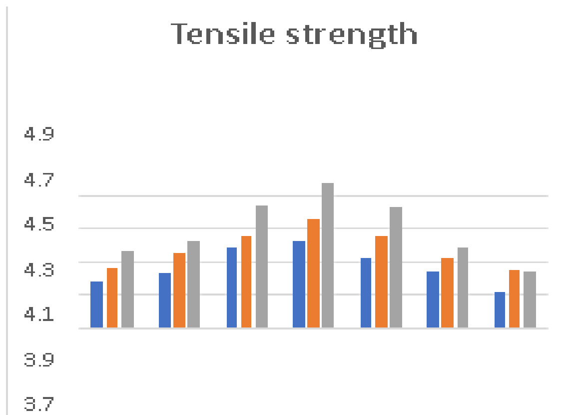

Fig 6 Split Tensile Strength Test

FLEXURAL STRENGTH TEST

Table: 11 Flexural strength Test

S.NO	% Replacement	Flexural Strength		
		7 days	14 days	28 days
1	0% CS + 0%ESP	5.02	5.35	5.80
2	5% CS + 5%ESP	4.89	5.15	5.69
3	10% CS +10% ESP	4.74	5.02	5.57
4	15% CS +15% ESP	4.65	4.78	5.25
5	20% CS +20% ESP	4.85	5.05	5.36
6	25% CS +25% ESP	5.12	5.45	5.75
7	30% CS +30% ESP	5.50	5.92	6.05

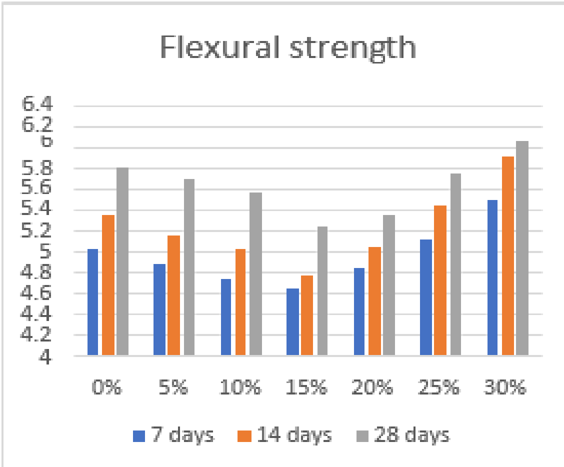

Fig 7 Flexural Strength Test

FLEXURAL STRENGTH RESULT BY USING ANSYS SOFTWARE

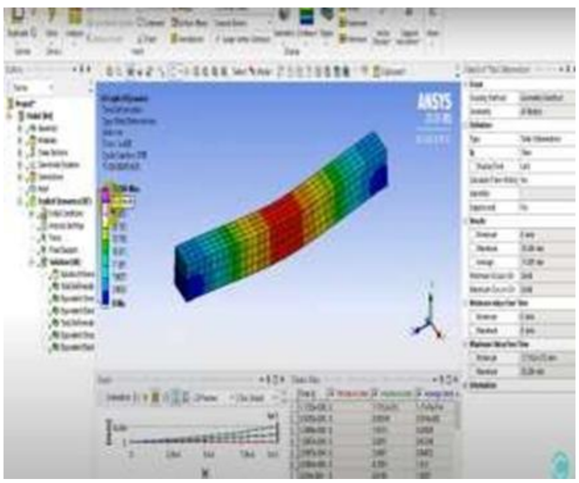

Fig 8 Flexural strength of Beam

VI. CONCLUSIO

1. The Cement, Fine aggregates and Coarse aggregate material qualities are within the permissible limits according to IS coderequirements, so we will use the materials for study.
2. Slump Cone value for the concrete increases with increasing in the percentage of copper slag and egg shell powder so the concrete was not workable.
3. The compaction factor value of concrete decreases with increases in the percentage of copperslag and egg shell powder.
4. The compressive strength of concrete at 15% replacement of copper slag and egg shell powder and is the optimum value for 7 days, 14 days and 28 days curing.
5. Split tensile strength for the cylindrical specimenis maximum at 15% of replacement of copper slag and egg shell powder.
6. The flexural strength of the beam is also maximum at 15% replacement of copper slag and egg shell powder.
7. So, the replacement of 15% of concrete with copper slag and egg shell powder is generally useful for better strength values in M40 grade of concrete.

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